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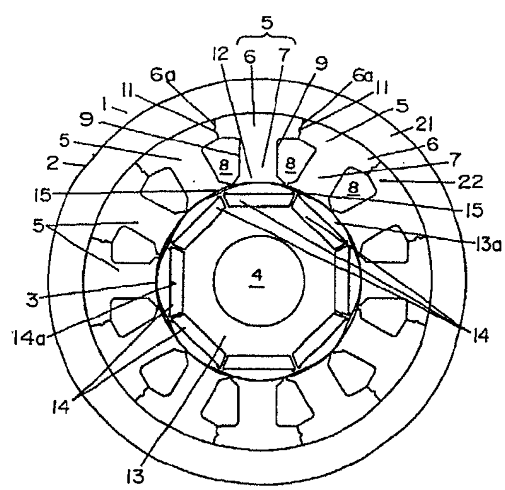
(54) MOTOR

(57) The invention relates to a motor comprising a stator core (22) having plural teeth (7) and slots (8) provided among the teeth (7), a winding (23) applied on the teeth (7) by a single turn, and a rotor (13) incorporating plural permanent magnets (14), which is rotated and driven by utilizing reluctance torque in addition to magnet torque. By turning thus divided teeth (7) by a single winding, the occupation rate of the winding in the slots (8) can be raised. As a result, a motor of small size and large output can be presented.

Fig. 1



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Description

TECHNICAL FIELD

The present invention relates to a synchronous motor comprising a stator for generating a rotary magnetic field, for rotating and driving by making use of a reluctance torque.

BACKGROUND ART

In a conventional general synchronous motor, a stator is formed by integrally projecting plural teeth from a ring-shaped yoke to its inner circumferential side. This stator is fabricated by laminating stator plates having plural teeth projecting to the inner circumferential side. It also comprises a stator core forming slots among these teeth, and windings are wound in these slots by distributed winding. The distributed winding is a winding method for winding distant teeth through slots. The rotor is composed by burying plural permanent magnets for magnetic poles in the outer circumference of the rotor core, and mounting a rotary shaft in the center.

In this way, by burying permanent magnets inside the rotor, the permanent magnet buried motor can utilize not only the magnet torque but also the reluctance torque, in which the reluctance torque is generated in addition to the magnet torque by the permanent magnets, as an inductance difference occurs between the inductance Ld in the direction of d-axis which is a direction for coupling the center of permanent magnet and the rotor center, and the inductance Lq in the direction of q-axis which is a direction rotated 90 degrees of electrical angle from d-axis. This relation is shown in formula (1).

$$T = Pn \{\psi a \times Iq + 1/2(Ld - Lq) \times Id \times Iq\} \quad (1)$$

where

- Pn : number of pole pairs
- ψa : interlinkage magnetic flux
- Ld : d-axis inductance
- Lq : q-axis inductance
- Iq : q-axis current
- Id : d-axis current

Formula (1) shows a voltage equation of dp conversion. For example, in a surface magnet motor, since the permeability of permanent magnet is nearly equal to that of air, both inductance Ld and Lq in formula (1) are nearly equal values, and the reluctance torque portion expressed in the second term enclosed in braces in formula (1) does not occur.

In addition to the magnet torque, by utilizing the reluctance torque, if desired to increase the torque of the driving motor, according to formula (1), it is enough to increase the difference of (Ld-Lq). The inductance L, which expresses the degree of ease of passing of magnetic flux, is proportional to N^2 (number of turns of teeth) , and hence by increasing the number of turns on the teeth, the difference of (Ld-Lq) becomes larger, so that the reluctance torque can be increased. However, if the number of turns is increased in order to utilize the reluctance torque more, as the number of turns increases, the winding group projecting to the stator end surface, that is, the coil end becomes larger. Hence, to rotate and drive the motor efficiently, if attempted to make use of the reluctance torque, the coil end becomes larger, and the motor itself is increased in size.

In the distributed winding, moreover, by turning windings plural times, a winding ring is formed, and this winding ring is inserted into teeth, and the periphery of the winding ring becomes longer than the periphery of teeth. Still more, in the distributed winding, since the teeth are wound through slots, the windings cross each other. Thus, in the distributed winding, the winding projects from the stator end, and the windings cross each other to increase the size of the coil end.

Hence, if attempted to drive the motor efficiently by making use of the reluctance torque, the motor size becomes larger. To the contrary, if the motor is reduced in size, the output of the motor drops.

In the air-conditioner, refrigerator, electric vehicle, etc., however, a motor of large output and small size is required.

Incidentally, the magnetic pole portion at the end of teeth in the stator is formed wider in the peripheral direction. Between the adjacent magnetic pole portions, however, since openings are formed for laying down windings in the slots, the interval of ends of teeth must be formed wider in the peripheral direction. That is, because of the distributed winding, an opening for inserting the winding ring in the teeth is needed. Incidentally, the gap between the stator inner circumference and the rotor outer circumference is generally set uniform on the whole periphery except for the openings of the slots.

In such conventional constitution, at the stator side, since there is an opening for a slot between magnetic pole portions, an insulating portion in the peripheral direction is formed in the distribution of the magnetic flux leaving the magnetic pole portions, which produced a problem of occurrence of cogging torque during rotor rotation. At the rotor side, when the distribution of the magnetic flux leaving its outer circumference is brought closer to sine waveform, the cogging torque can be decreased, but since the gap between the stator inner circumference and rotor outer circumference is uniform, the magnetic resistance in this gap is constant on the whole periphery, and in the joining portions the ends of the permanent magnets, the magnetic flux distribution changes suddenly, and the cogging torque increases. Thus, the cogging torque increasing factors are combined at the stator side and rotor side, and a large cogging torque was caused.

SUMMARY OF THE INVENTION

In the light of the problems of the prior art, it is hence an object of the invention to present a motor of large output and small size, and moreover a motor of small cogging torque.

The motor of the invention comprises a stator core having plural teeth and slots provided among these teeth, a winding making a single turn around the teeth, and a rotor incorporating plural permanent magnets, being constituted to rotate and drive by making use of reluctance torque, in which the winding does not cross because of a single turn, and the coil end can be decreased in size.

Moreover, in the core composed by combining plural independent core elements in an annular form, since the winding is turned in the portion of a slot recess formed at both sides of the teeth of the core element, and the winding is turned in a state of core element, the winding can be applied on the stator in neat arrangement. Moreover, since the winding is not turned in the adjacent state of teeth, it is not necessary to keep a wide opening between the ends of teeth, so that the interval of ends of teeth can be narrowed.

Further, in the stator core composed by coupling ends of plural core elements, and folding the core element group with bent ends into an annular form, since the winding is turned in the slot shape recess portion formed at both sides of the teeth of the core elements , when winding around the teeth, the end interval of teeth can be widened, and the winding can be applied around the teeth in neat arrangement. Moreover, since the ends are coupled, position setting when assembling is easy.

Further, the clearance between the confronting surface of teeth of the permanent magnet and the outer circumference of the rotor core is wider in the central part than in the end portion of the permanent magnet, and the reluctance torque can be utilized effectively.

Further, since the shape of the permanent magnet is projecting toward the center of the rotor in its middle, the reluctance torque can be utilized effectively.

Further, since the width between the adjacent permanent magnets is 0.15 to 0.20 of the width of teeth confronting two magnetic poles (two permanent magnets), the torque ripple of the motor can be suppressed.

Further, the leading end of the magnetic pole portion of the inner circumferential side of the teeth is projecting in the peripheral direction across a slight gap between the ends of teeth, and the gap between the teeth and rotor outer circumference is nearly constant, so that useless magnetic flux does not flow at the ends of teeth.

Further, as the leading end of the magnetic pole portion of the inner circumferential side of the teeth is projecting in the peripheral direction so as to connect between ends of the teeth, the gap between the teeth and rotor outer circumference may be continuous.

Further, by setting the width b of the opposite sides of the ends of teeth at $b < 0.6$ mm, the magnetic flux is saturated at the ends of the teeth.

Further, the incorporated permanent magnets are thinner in thickness of the permanent magnet positioned ahead in the rotor rotating direction than in the thickness of the permanent magnet rear portion, so that the quantity of the permanent magnets may be decreased without lowering the torque.

Further, the profile of the adjacent portions of the permanent magnets is a recess form corresponding to the disk-shape profile positioned outside of the center of the permanent magnet, and the magnetic resistance is increased in the adjacent portions of the permanent magnets, so that the magnetic flux distribution may be close to a sine waveform.

Further, the length of the rotor outer recess positioned outside of the adjacent portions of the permanent magnets should be properly corresponding to the angle of 0.2 to 0.4 of the central angle of the one pole portion of the rotor core.

Further, the gap between the rotor outer recess and teeth should be properly two times or more of the gap between the rotor outer circumference and the teeth.

Further, when the incorporated permanent magnets have two layers, the q-axis inductance increases, and the reluctance torque portion is maximized.

Further, the interval is properly a value set larger than 1/3 of the width of the teeth.

Further, when the winding is a flat square wire, the occupation rate can be enhanced than in the case of round wire. In particular, the winding of flat square wire is suited to concentric concentrated winding around the teeth.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of a motor in embodiment 1 of the invention, Fig. 2 is a partial sectional view of a stator in embodiment 1, Fig. 3 is a partial sectional view of a rotor in embodiment 1, Fig. 4 is a diagram showing a core element of embodiment 1, Fig. 5 is a sectional view of a motor in embodiment 2 of the invention, Fig. 6 is a sectional view of a motor in embodiment 3 of the invention, Fig. 7 is a sectional view of a motor in embodiment 4 of the invention, Fig. 8 is a sectional view of a motor in embodiment 5 of the invention, and Fig. 9 is a partial sectional view of a core element group in embodiment 5.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to Fig. 1 through Fig. 4, embodiment 1 of the invention is described below.

In Fig. 1, reference numeral 1 is a synchronous motor which rotates by utilizing reluctance torque, as well as magnet torque, and it is composed of a stator 2, a rotor 3, and a rotary shaft 4.

The stator 2 is composed of a ring-shaped frame

21, a stator core 22 combining plural independent core elements 5 made of high permeability material in an annular form, and a winding wound around slots 8 formed between teeth 7, 7 of each core element 5, and when a current is applied to these winding groups, a rotary magnetic field is generated.

The stator core 22 is composed by combining the plural core elements 5 in an annular form on the outer circumference 6 thereof, and fitting and fixing in the inner circumference of the frame 21, and each outer circumference 6 is formed in an entire shape of a sector form in which the extension line of both side surfaces 6a passes through the stator center. In the core elements 5, as specifically shown in Fig. 2, slot forming recesses 9 are formed in the inner circumferential portion, and slots 8 are formed in the slot forming recesses 9, 9 in the adjacent teeth 7, 7. At both side surfaces 6a, stopping portions 11 composed of engaging bumps 10a and engaging recesses 10b for engaging with each other when the core elements 5 are combined in an annular form are provided, so that the core elements 5 may be mutually fixed firmly. The core elements 5 are combined by welding, or they may be also fixed by crimping by forming fitting parts at the side of the core elements 5.

In this way, the stator 2 is formed by combining plural core elements 5. Hence, instead of turning the winding around the stator 2, the stator 2 can be formed after turning the winding around the core element 5. Thus, by winding in the state of core elements 5, since the winding is turned in every core element 5, single winding (concentrated winding) may be formed easily. That is, as shown in Fig. 4, when turning the winding, as shown in Fig. 4, there is no disturbing position for winding at the side surface of the teeth 7. As a result, the winding port of the turning device rotates about the teeth 7, so that an arrangement winding may be formed through an insulating film 24. Moreover, the turning precision of the winding 40 may be enhanced, and the arrangement winding may be formed easily.

Thus, by forming the winding of the stator 2 as a single winding, mutual crossing of winding at the stator end can be suppressed. As a result, since the winding is not crossed at the end of the rotary shaft direction of the stator 5, the size of the coil end can be suppressed. Moreover, by winding in the divided state of the stator, the periphery of the teeth 5 and one turn of the winding can be equalized in length. As a result, the winding does not project at the stator end, and the coil end may be reduced in size.

Further, because of winding in the divided state of the stator 5, it is not necessary to consider the space of the winding port of the winding device when winding, and the winding can be overlaid as much as possible. Besides, since the stator 5 is divided when winding, the precision of the winding device is heightened, and an arrangement winding may be formed. As a result, the occupation rate in the slot is heightened. Since the reluctance torque is proportional to the number of turns, the reluctance torque can be enhanced by raising the occupation rate.

In this way, since the winding around the teeth can be turned in a proper length, there is no extra winding, and the winding length can be shortened for the total number of turns. As a result, the copper loss is decreased, and the heat generation of the winding can be decreased.

Furthermore, since the interval d of ends of teeth does not require the space for passing the winding through the winding port of the device, the interval d of ends of teeth can be reduced. As a result, gap changes between the teeth and rotor outer circumference are smaller, and the cogging torque decreases.

Hitherto, in the case of single winding on the stator 2 by a turning device, it was possible to wind at an occupation rate of about 30%. However, after winding on the core element 5, when assembled, the wire filling rate in the slot 8 can be set more than 30%, or even the wire filling rate may be set even more than 60%.

The magnetic pole portions 12 of the inner end side from the slot forming recesses 9 of the core elements 5 are projected long to both sides in the peripheral direction, and across a slight gap d between the ends, the magnetic pole portions 12 of adjacent core elements 5 are connected, so that there may be no interruption in the distribution of magnetic flux in the peripheral direction from the magnetic pole portion 12 of each core element 5. Besides, both sides 12a of the magnetic pole portion 12 are formed nearly in a triangular shape so that the width in the radial direction may be smaller toward the end, thereby decreasing the magnetic leak between the magnetic pole portions 12, 12 of the adjacent core elements 5, 5 by increasing the magnetic resistance at both sides of the magnetic pole portion 12.

The slight gap d in embodiment 1 is $0 < d < 0.2$ mm. The slight gap d is formed by assembling after winding on the core element 5, and by opening such small gap, the magnetic leak from the winding of the slot 8 can be suppressed, and the cogging torque becomes smaller. The gap d of $0 < d < 0.2$ mm is a value obtained by experiments, and the cogging torque is decreased efficiently at this value. By not contacting the ends completely, it is effective to suppress flow of useless magnetic flux between the adjacent teeth 7.

This gap d may be set to 0 if the magnetic flux leak between adjacent core elements 5, 5 can be ignored and there is no problem in assembling precision, so that the cogging torque can be eliminated.

On the confronting surfaces of the ends of teeth of the teeth 7 (the end of teeth 7, being the side confronting between the ends of the teeth 7), b is properly at $b < 0.6$ mm. By defining b in a range of $b < 0.6$ mm, magnetic saturation occurs at the end of the teeth 7, and useless magnetic flux leak can be decreased.

On the other hand, the rotor 3 comprises a rotor core 13 made of high permeability material so that the magnetic flux of the rotary magnetic field produced by

the winding group of the stator 2 may pass easily, and permanent magnets 14 incorporated in the rotor core 13 at equal intervals in the peripheral direction corresponding to the poles on the rotor 3. These permanent magnets 143 are disposed so that the S pole and N pole may be alternate in the peripheral direction.

The teeth confronting surface 14a of the permanent magnet 14 is linear. The distance between the teeth confronting surface 14a and the outer circumference of the rotor 13 is wider in the middle part than at the end part of the permanent magnet 14. Thus, in the outer circumference of the rotor 13, having the easily passing portion and hardly passing portion of magnetic flux, it is possible to produce an inductance difference between the q-axis inductance and d-axis inductance, so that it is possible to rotate and drive by making use of reluctance torque. Incidentally, the shape of the permanent magnet 14 may be a shape projecting in the middle portion toward the center of the rotor 13.

On the outer circumference of the rotor core 13, as shown specifically in Fig. 3, a linear cut-off portion 15 is formed at the adjacent end portions of the permanent magnets 14.

The outer circumference of the stator 2 is covered with a ring-shaped frame 21, and reinforces the core elements 5 integrated by welding. By using the frame 21 in this manner, even in the motor rotating at high speed, the core elements are fixed firmly. If the stator main body assembled from the core elements 5 has a sufficient strength, it is not necessary to reinforce by the frame 21.

In this constitution, the motor of the invention can be driven by utilizing the reluctance torque as well as the magnet torque. In spite of the occupation rate of over 60% of the slots 8 in the motor, the size of the stator is small.

Since the output torque of the motor rotated and driven by making use of reluctance torque in addition to magnet torque is in the relation as shown in formula (1), when the occupation rate of the slots 8 is raised, the difference of Ld-Lq becomes larger, and the output torque can be heightened. That is, since the inductance L is proportional to N^2 (number of turns), the greater the number of turns, that is, the higher the occupation rate in the slots 8, the higher becomes the output.

In the motor driven by utilizing the reluctance torque in addition to the magnet torque, when the stator 2 is assembled after turning a winding about the core elements 5, the occupation rate can be enhanced, so that high output and small size may be realized.

Incidentally, it was found by experiments that the torque ripple is decreased when the width of the adjacent permanent magnets is 0.15 to 0.20 of the width of the teeth confronting two magnetic poles (two permanent magnets) (in 8 poles and 12 slots in Fig. 1, three teeth correspond to two magnetic poles, and in the case of 8 poles and 24 slots, six teeth are equivalent).

In the rotor 3, in the adjacent end portions of the permanent magnets 14 on the outer circumference of the rotor core 13, a cut-off portion 15 nearly linear to the rotor outer recess is formed. By forming such cut-off portion 15, the gap between the stator 2 inner circumference and rotor 3 outer circumference becomes large in the adjacent end portions of the permanent magnets 14. Therefore, since the magnetic resistance is large in the gap, the magnetic flux distribution in the gap between the stator 2 inner circumference and rotor 3 outer circumference is closer to the sine waveform.

Meanwhile, the length of the rotor outer recess positioned outside of the portion between the adjacent permanent magnets is properly a length corresponding to an angle of 0.2 to 0.4 of the central angle of one pole of the rotor core.

The spatial gap h between the teeth 7 and cut-off portion 15 is required to be more than 2 times of the spatial gap between the teeth 7 and rotor outer circumference. In embodiment 1, it has been known by experiment that the spatial gap of the teeth 7 and the cut-off portion should be 0.7 to 1 mm.

Thus, in this embodiment 1, since the cogging torque generating factors at both stator 2 side and rotor 3 side can be suppressed, a synchronous motor of a small cogging torque can be presented.

By employing such motor in the compressor, refrigerator, air-conditioner, electric vehicle, etc., it is effective to reduce the size and widen the accommodation space.

The motor used in an electric vehicle is required to be small in size in order to keep a wide space in the compartment, and at the same time a motor capable of utilizing the current of the charger efficiently is needed. In the motor used in the electric vehicle, mostly, a flat square wire with sectional width of 4 mm or more and height of 1.5 mm is used. The large current flowing in the winding is 300 amperes or more. Rotating at 7000 to 15000 by passing a large current, it is effective to use a motor of short winding length and a small heat generation for the number of turns, as the motor of the invention. If arrangement winding is possible, the occupation rate may be further enhanced than in round wires.

It is very effective to use such motor of the invention in a motor passing a large current as in an electric vehicle.

The description herein relates to a motor using a single winding stator, utilizing reluctance torque in addition to magnet torque, by burying permanent magnets, but excellent effects are also obtained by incorporating gaps with low permeability materials or resin materials in the rotor, instead of the permanent magnets, and rotating and driving by utilizing the reluctance torque only. That is, excellent effects are obtained if a stator of single winding is used in a synchronous motor.

(Embodiment 2)

Embodiment 2 is described by referring to Fig. 5.

In Fig. 5, reference numeral 31 is a synchronous motor rotating mainly in a principal rotating direction F, by using reluctance torque in addition to magnet torque, and it is composed of a stator 32, a rotor 33, and a rotary shaft 34.

The stator 32 is composed of a ring-shaped frame, a stator core combining plural independent core elements 35 made of high permeability material in an annular form, and a winding wound around slots 38 formed between teeth 37, 37 of each core element 35, and when a current is applied to these winding groups, it is composed to generate a rotary magnetic field.

Permanent magnets 39 are buried inside the rotor 3 disposed in this stator 32. The shape of permanent magnets 39 is in V-form, and the permanent magnets project to the center of the rotor 33. By thus reverse projecting magnetic poles, the inductance difference of the d-axis and q-axis can be increased. The permanent magnet 39 is composed of a permanent magnet forward portion 39a and a permanent magnet backward portion 39b in the rotor normal rotating direction F. At this time, the thickness of the permanent magnet backward portion 39b is greater than the thickness of the permanent magnet forward portion 39a.

Such constitution is based on the following reason. In the permanent magnet backward portion 39b, the magnetic flux produced from the permanent magnet backward portion 39b and the magnetic flux produced from the teeth 39 may repel each other, possibly causing demagnetization of the permanent magnet backward portion 39b. In order to use a magnet capable of generating a magnetic force not to cause demagnetisation, a thick permanent magnet was used.

However, in the motor which rotates almost in the normal rotating direction F only, the permanent magnet forward portion 39a which is sucked by the suction force from the teeth does not cause demagnetization, and it is not required to be as thick as the permanent magnet backward portion 39b. Hence, the permanent magnet forward portion 39a may be thinner than the permanent magnet backward portion 39b. As a result, in the motor rotating almost always in the normal direction, if the quantity of permanent magnets is decreased, the characteristic is not lowered, so that the quantity of the permanent magnets can be decreased.

The teeth confronting surface of the incorporated permanent magnet backward portion 39b projects to the stator 35 side and is thicker than the permanent magnet forward portion 39a. However, the teeth confronting surface of the incorporated permanent magnet backward portion 39b may be symmetrical to the confronting surface of the permanent magnet forward portion 39a, and may project to the rotor center side.

In the buried magnets, a weight for adjusting the balance between the forward portion and backward portion during rotary drive may be buried in the rotor.

The shape of the permanent magnets is not limited to V-form, but may be linea. or arcuate.

(Embodiment 3)

A third embodiment is explained by referring to Fig. 6.

In Fig. 6, reference numeral 51 is a synchronous motor which rotates by making use of reluctance torque in addition to magnet torque, and it is composed of a stator 52, a rotor 53, and a rotary shaft 54.

The stator 52 is composed by combining plural independent core elements 55 made of high permeability material in an annular form. A winding is turned around slots 58 formed between teeth 57, 57 of each core element 55, and it is designed to generate a rotary magnetic field by applying a current in the winding group.

In the rotor 53, four sets of permanent magnets 59, 60 arranged to have N-pole and S-pole alternately are buried in the rotor core made of high permeability material, and fixed on a rotor shaft 54. The permanent magnet per pole is divided into two sections in the rotor radial direction, and is composed of an outside permanent magnet 59 and an inside permanent magnet 60. The permanent magnets 59, 60 are formed in a convex arc shape at the rotor center side, and the both ends 59a, 60a are extended to the position close to the rotor outer circumference. The gap between the outside permanent magnet 59 and inside permanent magnet 60 is almost a constant width, and a passage 61 of magnetic flux in the q-axis direction is formed in this gap portion.

The stator 52 has a specific number of teeth 57, a winding (not shown) is turned around each tooth 57. At this time, since the winding is applied on each core element 55, a single winding is applied. As an alternating current is given to the stator winding, a rotary magnetic flux is generated, and by this rotary magnetic flux, magnet torque and reluctance torque act on the rotor 53, so that the rotor 53 is driven by rotation.

The width M of the gap between the outside permanent magnet 59 and inside permanent magnet 60 is desired to be as small as possible considering the loss of electromagnetic force of the permanent magnets 59, 60. However, from the viewpoint of q-axis inductance Lq, it is desired to be as large as possible to increase it to such an extent not to cause magnetic saturation.

Accordingly, in embodiment 3, as the width not to induce magnetic flux saturation generated by the current flowing in the winding, the width M is set at about half of the width N of the teeth 56. Investigating the width M and the q-axis inductance Lq, it is known that the q-axis inductance Lq decreases suddenly when the width M becomes smaller than one-third of the width N of the teeth 57. On the other hand, if the width M becomes larger than the width N of the teeth 57, the q-axis inductance Lq hardly changes. According to the result of the investigation, it is known that the gap between the outside permanent magnet 59 and inside permanent magnet 60, that is, the width M should be set larger than 1/3 of the width N of the stator 57.

In embodiment 3, the magnetic flux path is formed of plural layers of permanent magnets, and although the number of plural layers is not limited, it is known from the experiment that the efficiency is the highest in two layers.

(Embodiment 4)

Referring now to Fig. 7 and Fig. 8, embodiment 4 is described below.

In Fig. 7, reference numeral 71 is a synchronous motor which rotates by utilizing reluctance torque in addition to magnet torque, and it is composed of a stator 72 and a rotor 73.

The stator 72 is composed of a ring-shaped frame 74, a stator core combining plural independent core elements 75 made of high permeability material in an annular form, and a winding 80 turned around slots 78 formed between teeth 77, 77 of each core element 75, and it is designed to generate a rotary magnetic field by applying a current in the winding group.

The core elements 75 connect the end portions of core elements 75 as shown in Fig. 8, and compose a core element group. The core element group has a space in a folding portion 81 at the end, so as to be folded easily. By composing the stator 72 by turning and folding the winding 80 in the core element group, the stator can be assembled and positioned easily. At this time, the core elements 75 may be connected by welding, or fixed by fitting the ring-shaped frame 74.

An annular stator may be composed of one core element group, or plural core element groups may be combined to compose the annular stator.

Instead of forming the stator, alternatively, by contact of the end faces of the core elements 75, the stator may be formed by fixing the core element group by using resin or the like.

INDUSTRIAL APPLICABILITY

As described herein, in the invent ion as set forth in claims 1 and 2, by a single winding, the winding does not project excessively to the stator end surface, and hence the coil end may be reduced in size.

Further, in the invention as set forth in claims 3, 4, 5, since the winding can be applied on a single core element or by expanding the interval of the adjacent teeth, turning is easy and an arrangement winding can be applied. It is not necessary to provide a space between slots necessary for turning the winding by the turning device. Hence, the occupation rate can be enhanced, and the reluctance torque acts efficiently, so that a motor of large output and small size can be presented. In the interval of ends of adjacent teeth, it is not necessary to consider turning of the winding, the interval of ends of adjacent teeth can be decreased, and it is effective to suppress cogging torque.

Further, in the motor as set forth in claims 6, 7, 8, 9, 10, the reluctance torque can be utilized efficiently.

Further, in the motor as set forth in claim 11, the torque ripple can be decreased.

Further, in the motor as set forth in claims 12, 13, the cogging torque can be reduced.

Further, in the motor as set forth in claim 14, the cogging torque can be eliminated.

Further, in the motor as set forth in claim 15, generation of useless magnetic flux at the adjacent teeth side can be suppressed.

Further, in the motor as set forth in claims 16, 17, the quantity of permanent magnets can be decreased.

Further, in the motor as set forth in claim 18, the balance is not broken, and stable rotary drive is realized.

Further, in the motor as set forth in claims 19, 20, 21, 22, 23, the magnetic resistance is increased in the adjoining portions of the permanent magnets so that the magnetic flux distribution may be close to a sine waveform, and thereby the cogging torque can be suppressed.

Further, in the motor as set forth in claims 24, 26, a magnetic path is formed between permanent magnets, and the directivity of the magnetic flux flowing in the rotor is excellent.

Further, in the motor as set forth in claim 25, the motor can be rotated and driven efficiently.

Further, in the motor as set forth in claim 27, the motor can be rotated and driven more efficiently.

Further, in the motor as set forth in claims 28, 29, the occupation rate can be raised, and a large output and a small size are realized.

Further, in the motor as set forth in claim 30, heat generation caused by large current can be suppressed, and the efficiency is improved.

Further, in the motor as set forth in claims 31, 32, 33, 34, a smaller size and a wider accommodation are realized.

List of Reference Numerals in Drawing Figures

1	Motor
2	Stator
3	Rotor
5	Core element
7	Tooth
8	Slot
9	Slot forming recess
12	Magnetic pole
13	Rotor core
14	Permanent magnet
15	Cut-off portion

Claims

1. A motor rotating and driving by utilizing reluctance torque, comprising a stator core having plural teeth and slots provided among teeth of said plural teeth

individually, a winding applied on the teeth by a single turn, and a rotor incorporating plural permanent magnets.

2. A motor rotating and driving by utilizing reluctance torque, comprising a stator core having plural teeth and slots provided among teeth of said plural teeth individually, a winding applied on the teeth by a single turn, and a rotor incorporating plural parts of low permeability.

3. A motor of claim 1, wherein said stator core composed by combining plural independent core elements in an annular form has said winding turned in the slot shape recess formed at both sides of the teeth of the core elements.

4. A motor of claim 1, wherein said stator core composed by coupling end portions of plural core elements, and folding the core element group having bending ends in an annular form has said winding turned in the slot shape recess formed at both sides of the teeth of the core elements.

5. A motor of claim 1, wherein said stator core composed by combining plural sets of core element groups coupling the end portions of plural core elements, and folding in an annular form has said winding turned in the slot shape recess formed at both sides of the teeth of the core elements.

6. A motor of claim 1, wherein the interval between the teeth confronting surface of the permanent magnets and the core outer circumference of said rotor is wider in the middle part than at the end portions of the permanent magnets.

7. A motor of claim 6, wherein the shape of said permanent magnets is formed in a flat plate.

8. A motor of claim 6, wherein the shape of said permanent magnets projects toward the center of the rotor in the middle.

9. A motor of claim 8, wherein the shape of said permanent magnets is in a V-form.

10. A motor of claim 8, wherein the shape of said permanent magnets is in an arc form.

11. A motor of claim 1, wherein the width of said adjacent permanent magnets is in a range of 0.15 to 0.20 to the width of teeth confronting to two magnetic poles.

12. A motor of claim 1, wherein the ends of magnetic poles at the inside of said teeth project in the peripheral direction across a slight interval between ends of said teeth.

13. A motor of claim 12, wherein the slight interval d between ends of said teeth is in a range of $0 < d < 0.2$ mm.

14. A motor of claim 1, wherein the ends of magnetic poles at the inside of said teeth project in the peripheral direction so as to connect between the ends of said teeth.

15. A motor of claim 14, wherein the width b of the confronting surface of the ends of said teeth is in a range of $b < 0.6$ mm.

16. A motor of claim 6, wherein said incorporated permanent magnets are greater in thickness in the permanent magnet backward portion positioned behind in the rotor rotating direction than in the permanent magnet forward portion.

17. A motor of claim 16, wherein the shape of said permanent magnets is in a V-form projecting toward the rotor center.

18. A motor of claim 16, wherein a weight for adjusting the balance of said incorporated permanent magnets is buried in the rotor.

19. A motor of claim 1, wherein the outline of adjacent portion of said plural permanent magnets is in a convex form to the outline of the circular shape positioned outside of the middle of said permanent magnets.

20. A motor of claim 19, wherein the outer circumference of said rotor positioned outside of the adjacent portion of said permanent magnets is a linear outer circumferential section of the rotor.

21. A motor of claim 19, wherein the length of outer circumferential concave portion of said rotor positioned outside of the adjacent portion of said permanent magnets corresponds to an angle of 0.2 to 0.4 of the central angle of one pole of the rotor core.

22. A motor of claim 19, wherein the interval of the outer circumferential concave portion of said rotor and said teeth is more than two times the interval of the outer circumference of said rotor and said teeth.

23. A motor of claim 19, wherein the width of the interval of the outer circumferential concave portion of said rotor and said teeth is in a range of 0.7 to 1 mm.

24. A motor of claim 8, wherein said incorporated per-

manent magnets are formed in plural layers.

25. A motor of claim 24, wherein said incorporated permanent magnets are formed in two layers.

26. A motor of claim 25, wherein the interval of said outside permanent magnet and said inside permanent magnet is a constant interval.

27. A motor of claim 26, wherein the interval is set larger than 1/3 of the width of teeth.

28. A motor of claim 1, wherein said winding is a flat square wire.

29. A motor of claim 28, wherein the section of said flat square wire is 4 mm or more in width and 1.5 mm or more in height.

30. A motor of claim 1, wherein said motor is rotated and driven at 300 amperes or more.

31. A compressor employing a motor of claim 1.

32. An electric vehicle employing a motor of claim 1.

33. An air-conditioner employing a motor of claim 1.

34. A refrigerator employing a motor of claim 1.

Fig. 1

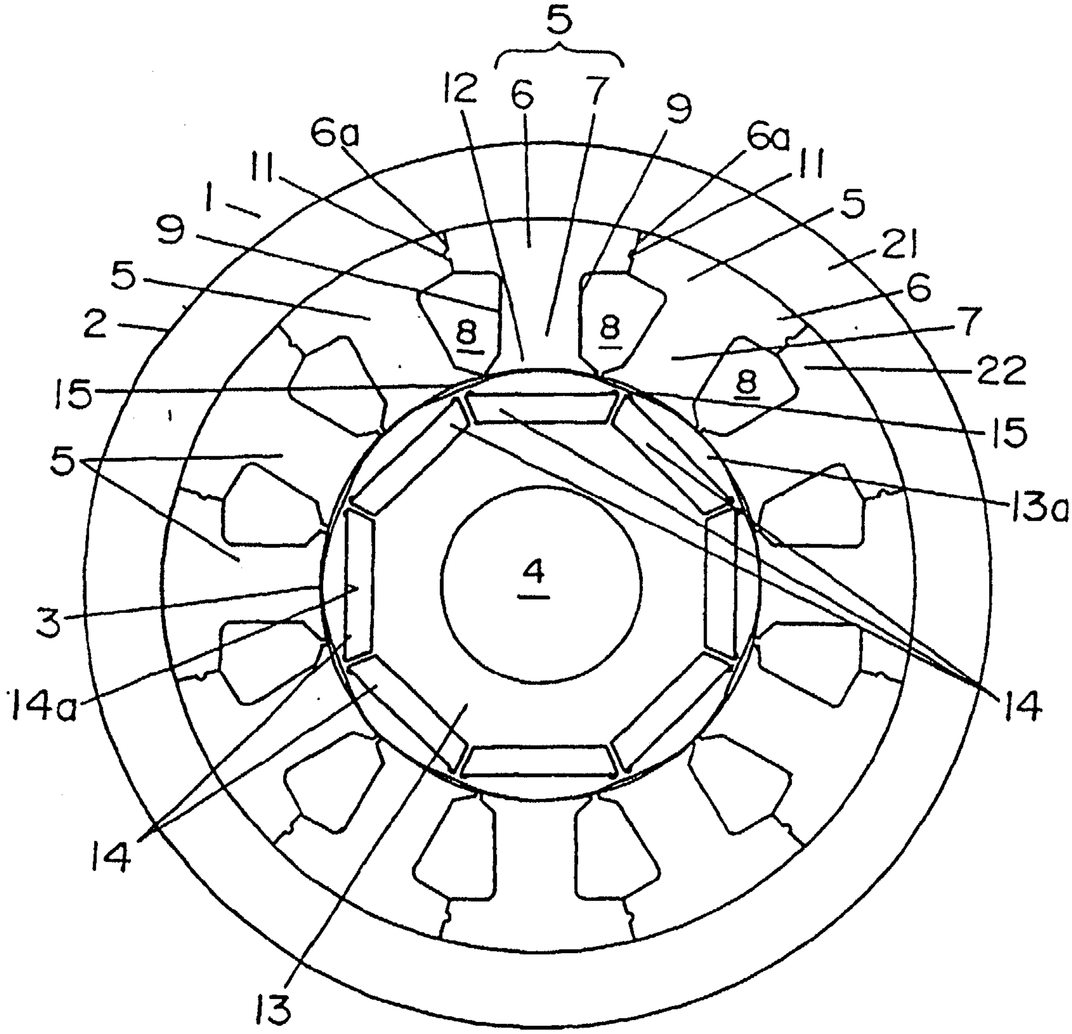
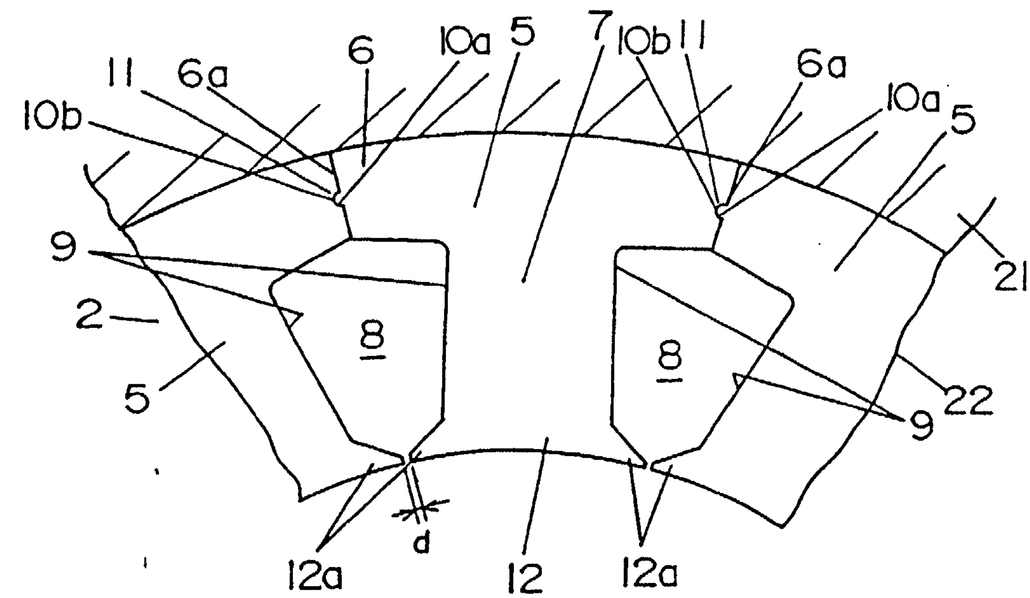


Fig. 2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6
10a
5
7
10b
11
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5
9
2
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8
8
21
22
9
12a
d
12
12a

Fig. 3

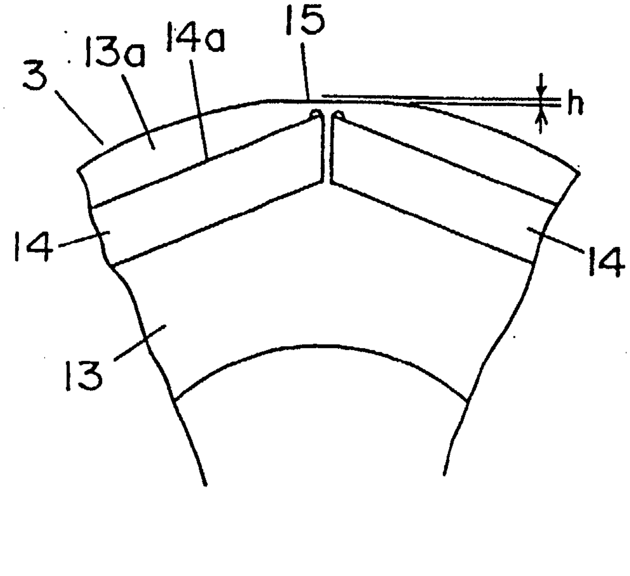

3
13a
14a
15
h
14
14
13

Fig.4

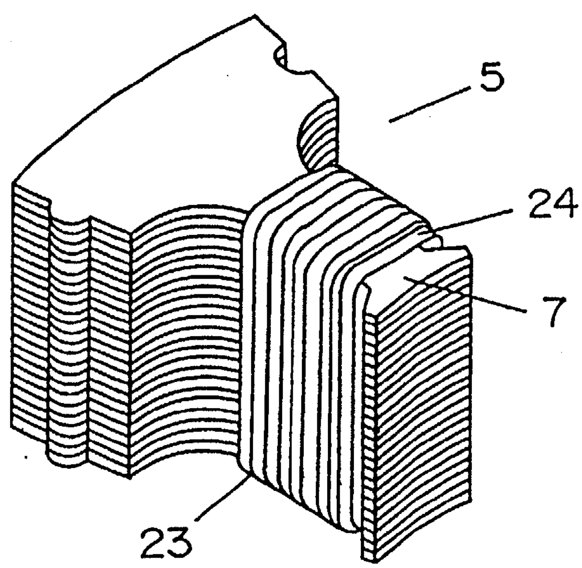


Fig.5

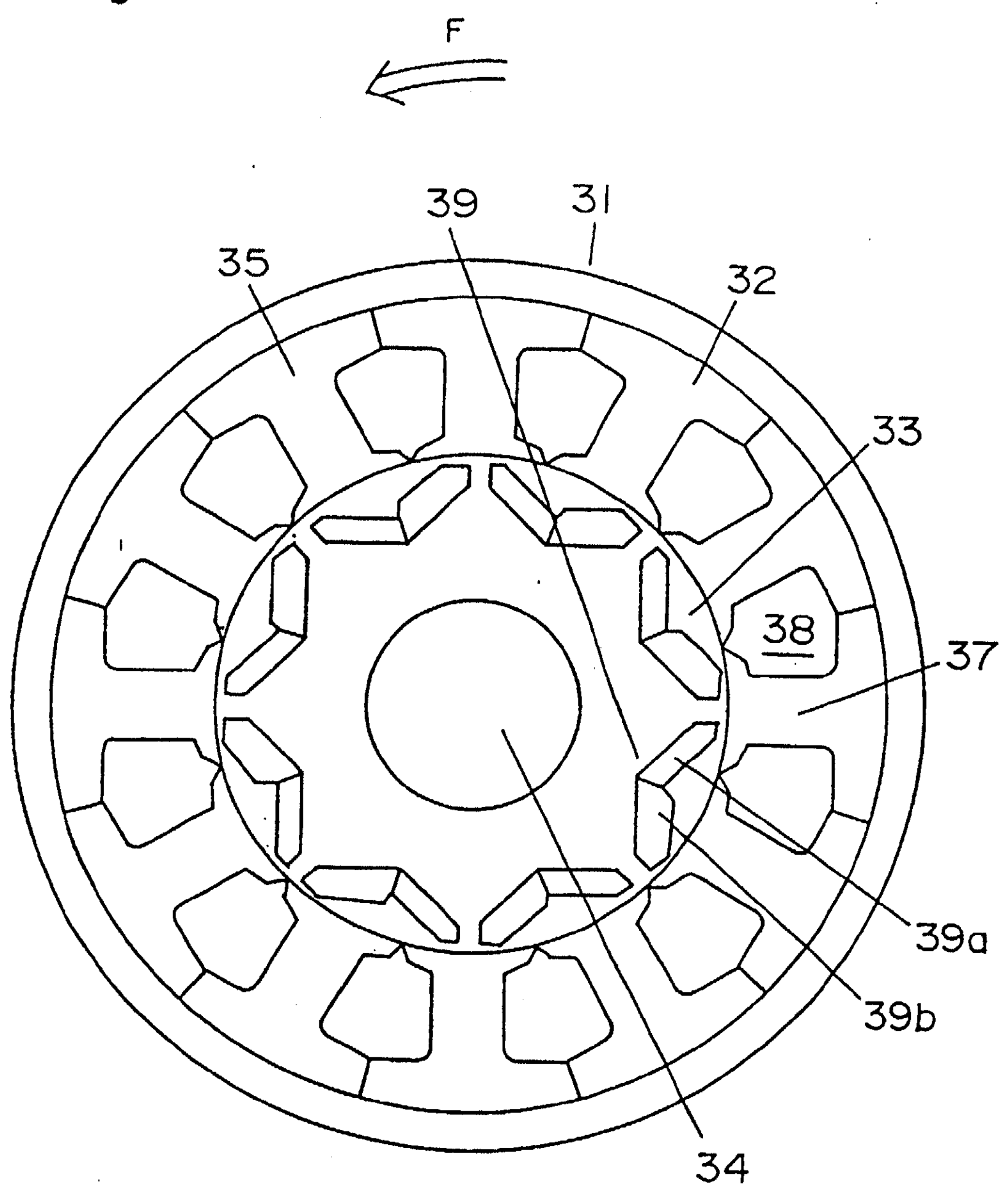


Fig.6

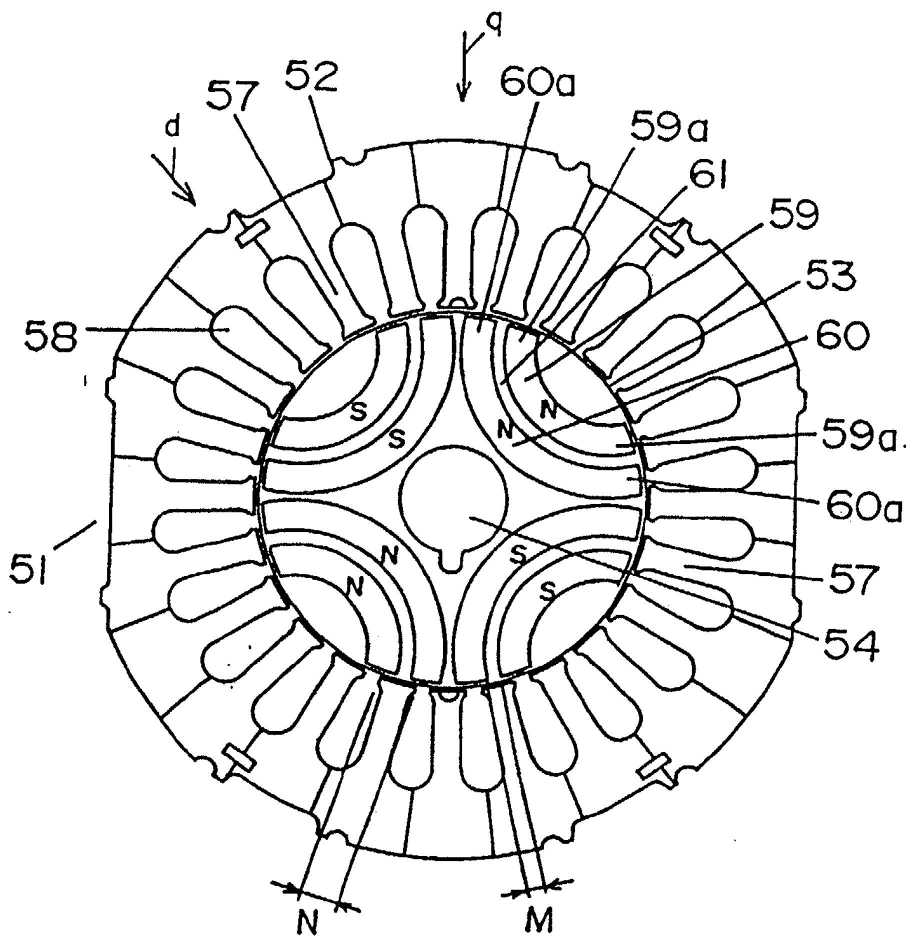


Fig.7

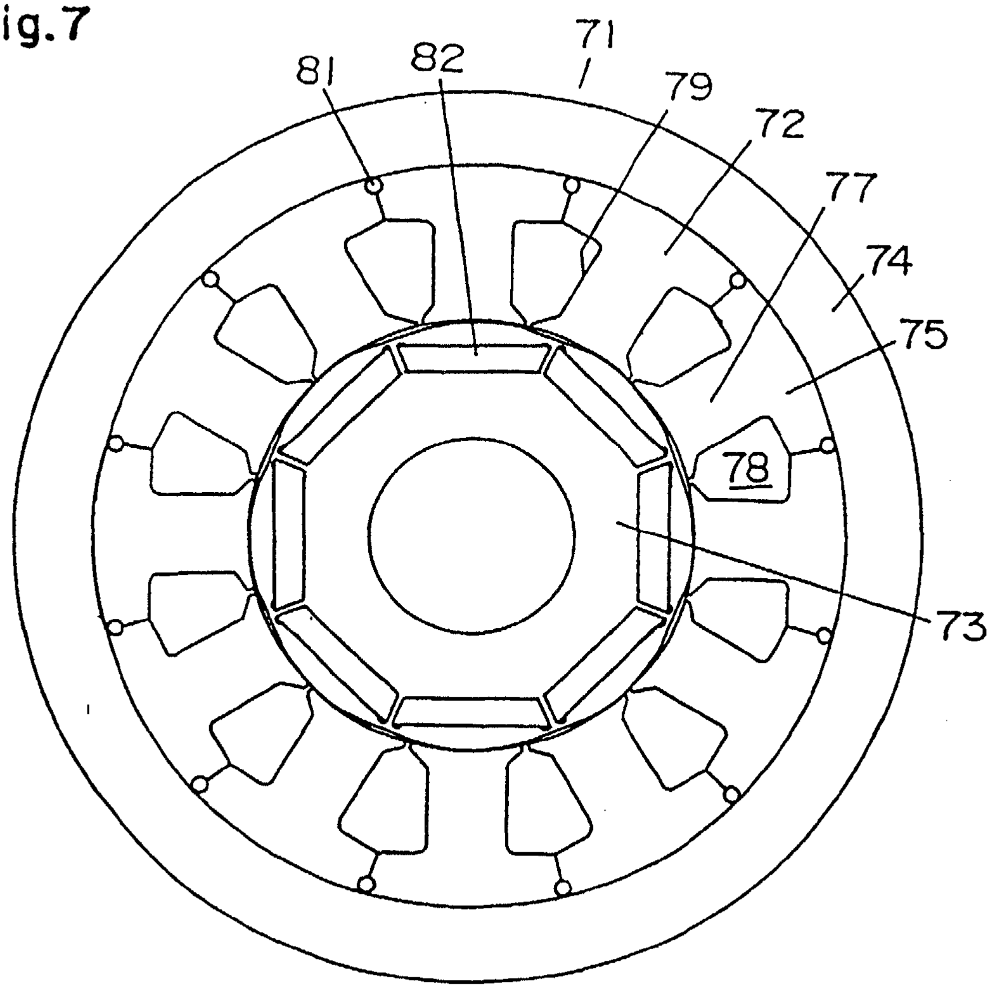
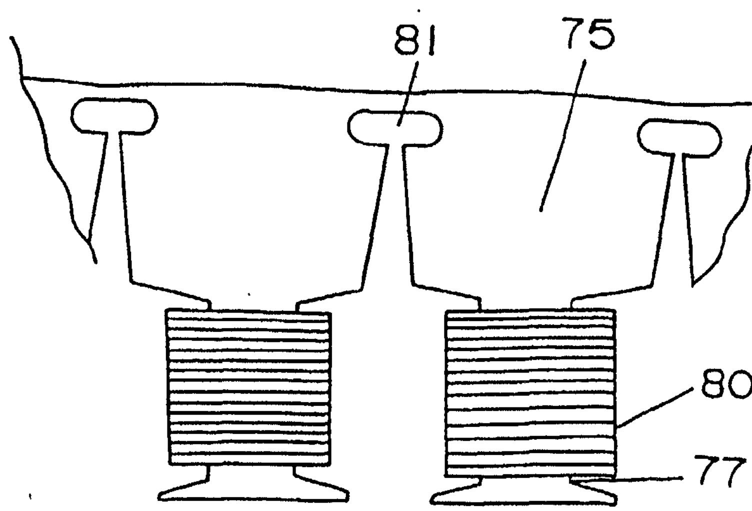


Fig.8



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/00489

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl[6] H02K21/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl[6] H02K21/14-21/16, H02K1/14-1/16, H02K1/27, H02K19/02-19/14, H02K29/00-29/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926 - 1997
Kokai Jitsuyo Shinan Koho	1971 - 1996
Toroku Jitsuyo Shinan Koho	1994 - 1997

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, 7-255138, A (Yaskawa Electric Corp.), October 3, 1995 (03. 10. 95), Claim 1; column 2, lines 43 to 47 (Family: none)	1, 3, 6, 11-13, 15, 30-34
Y		2, 4, 5, 7, 8-10, 14, 19-29
Y	JP, 7-303357, A (Okuma Corp.), November 14, 1995 (14. 11. 95), Column 5, lines 17 to 21; Fig. 8 (Family: none)	2
Y	JP, 5-292714, A (Mitsubishi Electric Corp.), November 5, 1993 (05. 11. 93), Column 3, lines 1 to 9; Fig. 3 (Family: none)	4, 5
Y	JP, 8-19196, A (Mitsubishi Electric Corp.), January 19, 1996 (19. 01. 96), Column 21, lines 22 to 36; Figs. 1, 2, 6, 7 (Family: none)	4, 5

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
May 20, 1997 (20. 05. 97)	May 27, 1997 (27. 05. 97)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/00489

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 7-20050, U (Yaskawa Electric Corp.), April 7, 1995 (07. 04. 95), Figs. 1, 4, 5 (Family: none)	7 - 10
Y	JP, 5-284677, A (Yaskawa Electric Corp.), October 29, 1993 (29. 10. 93), Fig. 1 (Family: none)	14
Y	JP, 7-236240, A (Sanyo Electric Co., Ltd.), September 5, 1995 (05. 09. 95), Fig. 4 (Family: none)	19 - 23
Y	JP, 6-66277, U (Yaskawa Electric Corp.), September 16, 1994 (16. 09. 94), Figs. 2, 4 (Family: none)	24 - 27
Y	JP, 62-160048, A (Shinko Electric Co., Ltd.), July 16, 1987 (16. 07. 87), Claim 1; Fig. 1 (Family: none)	28, 29